TEMPERATURE COMPENSATION ATTENUATOR

[0001] FIELD OF THE INVENTION

[0002] The present invention relates to temperature compensation attenuators for compensating temperature characteristics of high frequency or microwave devices and systems used in electronics and communication. The attenuators can be applied in various circuits and systems utilizing high frequency waves or microwaves, and more particularly, are suitable for use in mobile communication systems, satellite communication systems, satellite navigational systems, and radar systems which require strict temperature characteristics.

[0003] BACKGROUND OF THE INVENTION

[0004] Current techniques for reducing the temperature drift of high frequency or microwave active devices are quite complex, utilize many applied components, and exhibit lengthy R&D periods, high cost, and high rate of failure. For example, the gain of high frequency or microwave power amplifiers, and thus their power output, varies with external temperature, seriously deteriorating the characteristics and stability of the amplifiers and even of the entire systems. To reduce the variance in the gain and the power of high frequency or microwave power amplifiers resulting from the variance in environmental temperature, many active devices, such as temperature detectors, power couplers, wave detectors, programmable signal processors, storage, and preamplifiers with automatic gain control (AGC) and automatic power control (APC) capabilities are included in the amplifiers themselves, their power sources and their control systems.

[0005] While resolving the temperature drift characteristics, several features of the devices must be satisfied:

(1) wideband characteristic;

(2) minimal refection coefficient for both the input and the output terminals;

(3) high isolation for both the input and the output terminals;

(4) the characteristic impedance of both the input and the output terminals complies with the requirement of the access system, for example, 50 Ohm or 75 Ohm.

[0006] SUMMARY OF THE INVENTION

[0007] The objective of the present invention is to provide a temperature compensation attenuator to realize the compensation of the temperature characteristic of high frequency or microwave active devices and systems in electronics and communications.

[0008] In one embodiment of the invention described herein provided is a temperature compensation attenuator comprising a base, a film thermistor on the base, an input terminal and an output terminal which are connected to the two ends of the film thermistor respectively, and a film resistor, wherein the top side of the resistor is electronically connected to the bottom side of the thermistor, and the bottom side of the resistor is electronically connected to a ground terminal.

[0009] In certain embodiments of the invention, the two ends of the resistor are connected to an input terminal and an output terminal, respectively.

[0010] In certain embodiments of the invention, the resistor is a film thermistor with a temperature characteristic opposite to that of the film thermistor on the base.

[0011] As a result, by utilizing the film thermistor of the present invention, a wideband temperature compensation attenuator with a distributed parameter circuit structure is constructed wherein the amount of attenuation varies with temperature. By connecting the temperature compensation attenuator of the present invention to a high frequency or microwave active circuit, it can compensate for the variance of the gain of the high frequency or microwave active device or the drift of the frequency characteristic of the active device resulting from temperature variance. Even under large environmental temperature variance, it can still ensure the stability of the gain of the high frequency or microwave active device and compensate for the drift of the frequency characteristic of the active device.

[0012] BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **Fig. 1** is a schematic drawing of the temperature compensation attenuator with a distributed parameter circuit structure in accordance with a first preferred embodiment of the present invention.

[0014] **Fig. 2** is a circuit schematic drawing of the temperature compensation attenuator of **Fig. 1**.

[0015] **Fig. 3** is a schematic drawing of the temperature compensation attenuator with a distributed parameter circuit structure in accordance with a second preferred embodiment of the present invention.

[0016] **Fig. 4** is a circuit schematic drawing of the temperature compensation attenuator of **Fig. 3**.

[0017] **Fig. 5** is a theoretical curve of the resistance value of the thermistor in series and the resistance value of the thermistor in parallel under ideal conditions with the temperature variance of the present invention.

[0018] **Fig. 6** is a curve of the amount of attenuation or gain when expressed by gain of the temperature compensation attenuator with the temperature variance of the present invention.

[0019] **Fig. 7** is a schematic drawing of the variance of the gain of the amplifier where the temperature compensation attenuator is coupled in front of the device of the present invention.

[0020] **Fig. 8** is a schematic drawing of the active device where the temperature compensation attenuator is coupled in front of the device of the present invention.

[0021] DETAILED DESCRIPTION OF THE INVENTION

[0022] With reference to **Fig. 1**, the temperature compensation attenuator in accordance with the first preferred embodiment of the present invention comprises a base **6**, a film thermistor **1** disposed on the base **6**, wherein the two ends of the film thermistor **1** are connected to an input terminal **3** and an output terminal **4** respectively, the bottom side of the film thermistor **1** is electronically connected to the top side of the film resistor **2**

formed on the surface of the base **6**, and the bottom side of the film resistor **2** is electronically connected to the ground terminal **5**.

[0023] In one aspect of the present embodiment, a film thermistor with a temperature characteristic opposite to that of the film thermistor **1** can be selected for the film resistor **2** to realize a better temperature compensation characteristic of the temperature compensation attenuator.

[0024] As described hereinafter, the film resistor **2** will be understood to be a film thermistor.

[0025] Due to the difference in their resistance values and the temperature coefficients, the formation of the film thermistor **1** and the film resistor **2** on the surface of the base **6** will be realized respectively through masking technology. Firstly, the film thermistor **1** is printed on the base **6**, wherein one end of the film thermistor **1** is connected to the input terminal **3**, and the opposite end is connected to the output terminal **4**; and then the film resistor **2** is printed on the base **6**, wherein the top side of the film resistor **2** is electronically connected to the bottom side of the film thermistor **1**, and the bottom side of the film resistor **2** is electronically connected to the ground terminal **5**. In the end, the surfaces of the film thermistor **1** and the film resistor **2** are coated with protective layer to avoid the invasions of external moisture and dust.

[0026] **Fig. 2** illustrates the circuit schematic drawing of the distributed parameters of the temperature compensation attenuator of **Fig. 1**. As shown in **Fig. 2**, the combination of the film thermistor **1** and the film resistor **2** can be equivalent to a two port resistor network constructed with numerous tiny series and parallels. According to the required compensation amount of gain temperature (that is the required amount of attenuation, isolation, and reflection coefficient of the two port network at different temperatures), the resistance value of the unit's width and length, and the temperature coefficient of the film thermistor **1** and film resistor **2** are determined. It is clear from the calculation that, to obtain a temperature compensation attenuator with a small reflection coefficient and a high isolation of the output and input terminals, the temperature coefficient of the film thermistor **1** and that of the film resistor **2** of the temperature compensation attenuator

needs to have different characteristics with respect to the temperature variance. If both the film thermistor **1** and the film resistor **2** have the same positive or the same negative temperature coefficient, the solution would not comply with the requirement to obtain a temperature compensation attenuator with a small reflection coefficient and a high isolation of the output and input terminals.

[0027] In the present embodiment, for temperature compensation of a high frequency or microwave active device having a decreasing gain and power with the increase in temperature, in order to keep the gain and the power free from the temperature variance, a thermistor with a negative temperature coefficient (wherein the resistance value decreases with the increase of the temperature) is adopted for the film thermistor **1**, while a thermistor with a positive temperature coefficient (wherein the resistance value increases with the increase of the temperature) is adopted for the film resistor **2**.

[0028] In the present embodiment, as the temperature increases, for temperature compensation of a high frequency or microwave active device having an increasing gain and power with the increase in temperature, in order to keep the gain and the power free from the temperature variance, a thermistor with a positive temperature coefficient (wherein the resistance value increases with the increase of temperature) is adopted for the film thermistor **1**, while a thermistor with a negative temperature coefficient (wherein the resistance value decreases with the increase of temperature) may be adopted for the film resistor **2**.

[0029] In the present embodiment, as the temperature varies, for the temperature compensation attenuator to operate wherein the required compensation of the attenuation is small, the absolute value of the temperature coefficient of the film thermistor **1** that is much greater than that of the film resistor **2** is required.

[0030] In the present embodiment, as the temperature varies, for the temperature compensation attenuator to operate wherein the required compensation of the attenuation is large, the absolute value of the temperature coefficient of the film thermistor **1** that is about equal to that of the film resistor **2** is required.

[0031] Based on the package structure of the electrode, a surface mount type temperature compensation attenuator can be made, while a pin leg lead type and a patch cord type are also feasible.

[0032] The characteristic impedance of the input and output terminals need to be designed to comply with that required by the access system, e.g., 50 Ohm.

[0033] With reference to **Fig. 3**, the difference of the temperature compensation attenuator in accordance with a second preferred embodiment of the present invention with that of the first preferred embodiment described hereinbefore is that the two ends of the film resistor **2** are connected to the input terminal **3** and the output terminal **4**, respectively.

[0034] The specific fabrication method is essentially the same as that described in the first preferred embodiment.

[0035] The temperature compensation attenuator in accordance with the second preferred embodiment of the present invention, comprises a base **6**, a film thermistor **1** formed on the surface of the base **6**, wherein the two ends of the film thermistor **1** are connected to an input terminal **3** and an output terminal **4**, respectively, the bottom side of the film thermistor **1** is electronically connected to the top side of the film resistor **2** formed on the surface of the base **6**, the bottom side of the film resistor **2** is electronically connected to the ground terminal **5**, and the two ends of the film resistor **2** are also connected to the input terminal **3** and the output terminal **4**, respectively.

[0036] In one aspect of the present embodiment, a film thermistor with a temperature characteristic opposite to that of the film thermistor **1** can be selected for the film resistor **2** in order to realize a better temperature compensation characteristic of the temperature compensation attenuator.

[0037] Due to their difference in the resistance value and the temperature coefficient, the formation of the film thermistor **1** and the film resistor **2** on the surface of the base **6** will be realized respectively through masking technology. Firstly, the film thermistor **1** is printed on the base **6**, wherein one end of the film thermistor **1** is connected to the input terminal **3**, and the opposite end is connected to the output terminal **4**; and then the film

resistor **2** is printed on the base **6**, wherein the top side of the film resistor **2** is electronically connected to the bottom side of the film thermistor **1**, and the bottom side of the film resistor **2** is electronically connected to the ground terminal **5**; and the two ends of the film resistor **2** are also connected to the input terminal **3** and the output terminal **4**, respectively. In the end, the surfaces of the film thermistor **1** and the film resistor **2** are coated with a protective layer to avoid the invasions of external moisture and dust.

[0038] **Fig. 4** illustrates the circuit schematic drawing of the distributed parameters of the temperature compensation attenuator of **Fig. 3**. As shown in **Fig. 4**, the combination of the film thermistor **1** and the film resistor **2** can be equivalent to a two port resistor network constructed by numerous tiny series and parallels. According to the required compensation amount of gain temperature (that is the required amount of attenuation, isolation, and reflection coefficient of the two port network at different temperatures), the resistance value of the unit's width and length, and the temperature coefficient of the film thermistor **1** and film resistor **2** are determined. In order to obtain a temperature compensation attenuator with a small reflection coefficient and a high isolation of the output and input terminals, the temperature coefficient of the film thermistor **1** and that of the film resistor **2** of the temperature compensation attenuator need to have different characteristics with respect to the temperature variance. If both the film thermistor **1** and the film resistor **2** have the same positive or the same negative temperature coefficient, the solution would not comply with the requirement to obtain a temperature compensation attenuator with a small reflection coefficient and a high isolation of the output and input terminals.

[0039] In the present embodiment, for temperature compensation of a high frequency or microwave active device having a decreasing gain and power with the increase in temperature, in order to keep the gain and the power free from the temperature variance, a thermistor with a negative temperature coefficient (wherein the resistance value decreases with the increase of the temperature) is adopted for the film thermistor **1**, while

a thermistor with a positive temperature coefficient (wherein the resistance value increases with the increase of the temperature) is adopted for the film resistor **2**.

[0040] In the present embodiment, for temperature compensation of the high frequency or microwave active device having an increasing gain and power with the increase in temperature, in order to keep the gain and the power free from the temperature variance, a thermistor with a positive temperature coefficient (wherein the resistance value increases with the increase of temperature) is adopted for the film thermistor **1**, while a thermistor with a negative temperature coefficient (wherein the resistance value decreases with the increase of temperature) is adopted for the film resistor **2**.

[0041] In the present embodiment, as the temperature varies, for the temperature compensation attenuator to operate wherein the required compensation of the attenuation is small, the absolute value of the temperature coefficient of the film thermistor **1** that is much smaller than that of the film resistor **2** is required.

[0042] In the present embodiment, as the temperature varies, for the temperature compensation attenuator to operate wherein the required compensation of the attenuation is large, the absolute value of the temperature coefficient of the film thermistor **1** that is about equal to that of the film resistor **2** is required.

[0043] The characteristic impedance of the input and output terminals need to be designed to comply with that required by the access system, e.g., 50 Ohm.

[0044] **Fig. 5** illustrates the theoretical curve of the resistance value per unit area of the film thermistor **1** with a negative temperature characteristic, and the resistance value per unit area of the film resistor **2** with a positive temperature characteristic. The temperature coefficient of the thermistor in series, that is of the film thermistor **1**, needs to have a temperature characteristic opposite to that of the thermistor in parallel, that is of the film resistor **2**.

[0045] **Fig. 6** illustrates the curve of the amount of attenuation or gain, when expressed by gain, of the temperature compensation attenuator relative to the temperature variance plotted in correspondence to the curve of **Fig. 5**. When designing and manufacturing a temperature compensation attenuator, by selecting the thermistor in series, that is the film

thermistor **1**, and the thermistor in parallel, that is the film resistor **2**, having characteristics in accordance with the curve of **Fig. 5**, the required variance of the attenuation of the temperature compensation attenuator with the temperature variance is realized.

[0046] **Fig. 7** illustrates the variance of the gain of the amplifier where the temperature compensation attenuator is coupled in front of a device. If the temperature increases, the gain of the amplifier will decrease, and since the temperature compensation attenuator is coupled into the system, the gain of the amplifier will be compensated, and thus a power system with a stable gain is constructed. Even under the conditions of varying environmental temperature, the gain and power output of the device such as the amplifier can be maintained free from the effects of the environmental temperature, namely, by swapping part of the gain for the stability of the system.

[0047] **Fig. 8** illustrates an active device where the temperature compensation attenuator is coupled in front of the device. Like with the amplifier, the temperature compensation attenuator can also be connected to other high frequency or microwave active devices, by coupling it, for example, in front of a high frequency or microwave diode power detector or a microwave attenuator, so that the drift of temperature characteristic of the high frequency or microwave active device can also be compensated.

[0048] In the preferred embodiments, it is understandable that the geometries of the film thermistor **1** and the film resistor **2** are not limited to a quadrangle. The form of the contact side of the film thermistor **1** with the film resistor **2** is not limited to single side contact. For example, in certain embodiment, one side of the film thermistor **1** is electronically contacted with multisides of the film resistor **2**, multisides of the film thermistor **1** are electronically contacted with one side of the film resistor **2**, or multisides of the film thermistor **1** are electronically contacted with multisides of the film resistor **2**, and so on.

[0049] In the preferred embodiments hereinbefore, the film thermistor **1**, the film resistor **2**, the input terminal **3**, the output terminal **4**, and the ground terminal **5** are without limitation in the same plane; they can also be in different planes.

[0050] The present invention discloses a temperature compensation attenuator with the gain and power level having a distributed parameter circuit structure. By connecting the temperature compensation attenuator of the present invention to a high frequency or a microwave active circuit, the variance of the gain of the high frequency or microwave active device or the drift of the frequency characteristic (RF) of the active device due to temperature variations is compensated. Even under adverse environmental temperature variance, an attenuator can ensure the stability of the gain of the high frequency or microwave active device or compensate the drift of the frequency characteristic (RF) of the active device.

[0051] The temperature compensation attenuator of the present invention provides the following advantages:

(1) It is an extremely wide band, a minimal reflection coefficient, and a preferable isolation performance.

(2) The passive characteristic offers the features of low cost, small size, simple process of manufacture, and good reliability, and is suitable for the terminal ends of light mobile communication.

(3) It does not need complicated control mode and device, and is easy and convenient to operate. For example, in order to compensate the variance of the gain or power of the high frequency or microwave power amplifier due to the temperature variance, the variation of the gain or power between the high temperature and the low temperature only needs to be measured. As required, the corresponding temperature compensation attenuator can be coupled in the front or in the back or even within the power amplifier and can compensate exactly for the variations of the gain or power.

(4) It is not needed to solve the synchronization problem of the signal.

(5) It is quite suitable for outdoor communication equipments or in adverse weather conditions, such as for a repeater of mobile communication, a tower amplifier of broadcast television, common antenna equipments, a high range frequency head of a satellite receiver, satellite navigation (GPS), wireless link (WLAN), and so on.

(6) It is suitable for the compensation of the variance of the gain or power of a hot power device, such as the variance of the gain or power due to the short term and long term hot status following the start up of a transmitter in a base station for mobile communications.

(7) It is suitable for an instrument or tester having a strict requirement on the indoor temperature variance.

(8) In accordance with the requirement of system installation, besides the surface mount type for the temperature compensation attenuator of the present invention, the pin leg lead type and the patch cord type are also offered.